Renewable Energy System Overview

NASA International Workshop on Pollution Prevention and Sustainable Development

November 1, 2006

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Presentation Overview

- Energy Policy Act of 2005 (EPACT 05) Federal RE Goal
- Renewable Resources & Costs
- Renewable Technologies
  - Solar
  - Wind
  - Biomass
  - Geothermal
- Renewable Power Purchasing Options & Information
- Federal Renewable Use
- FEMP and NREL Assistance
- Why are Renewables Important?

Federal Renewable Goal

- EPACT 05, Section 203a - 3% in FY07-09, 5% in FY10-FY12, 7.5% in FY13 & each fiscal year thereafter.

- Renewable Definition - electric energy generated from solar, wind, biomass*, landfill gas, **ocean** (including tidal, wave, current, and thermal), geothermal, municipal solid waste, or **new hydroelectric** generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project.

- Renewable energy amount shall be doubled if:
  - Renewable energy is produced on-site, on federal lands or on Native American land & used at a Federal facility

**There is a detailed biomass definition in the law*

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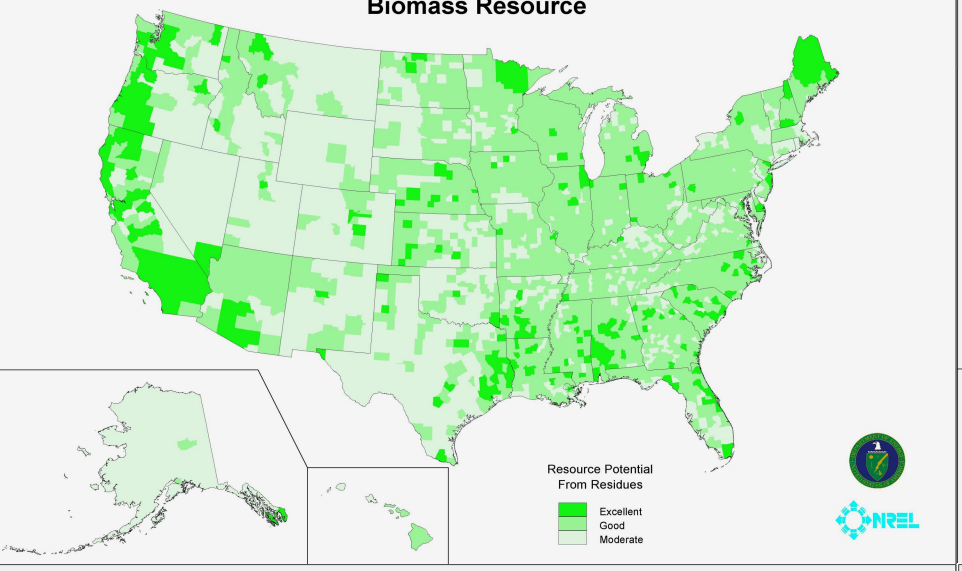
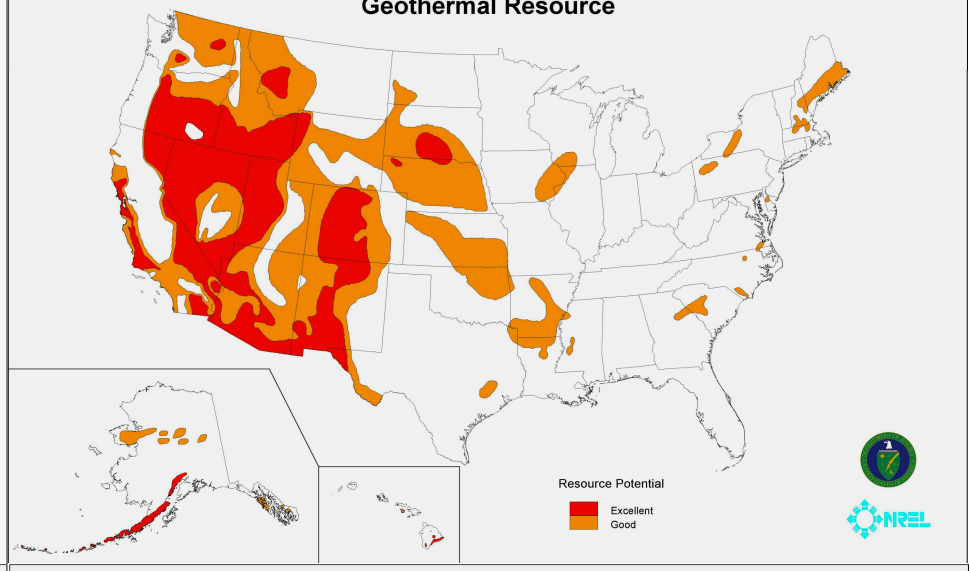
Renewable Resource Availability

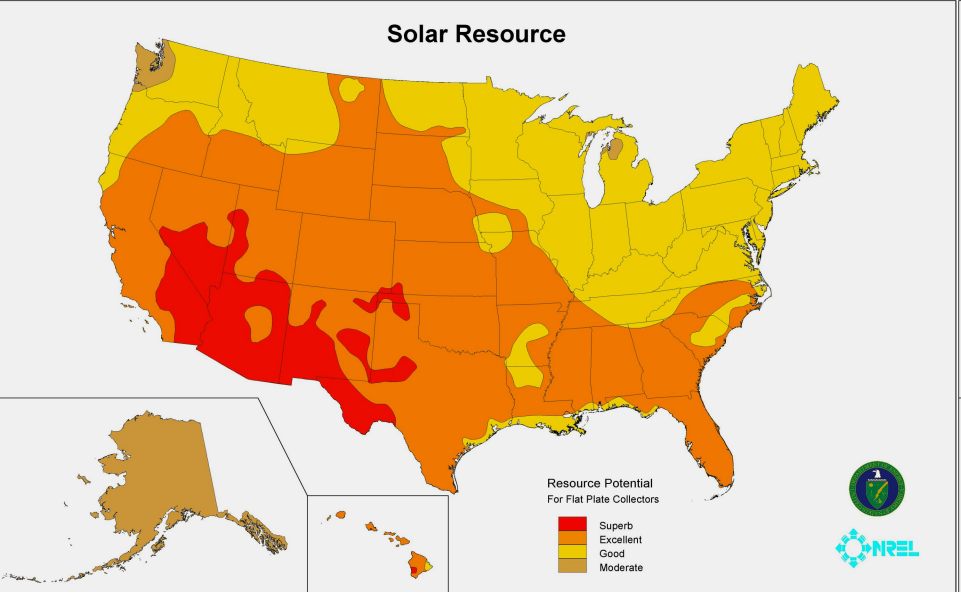
Biomass Resource



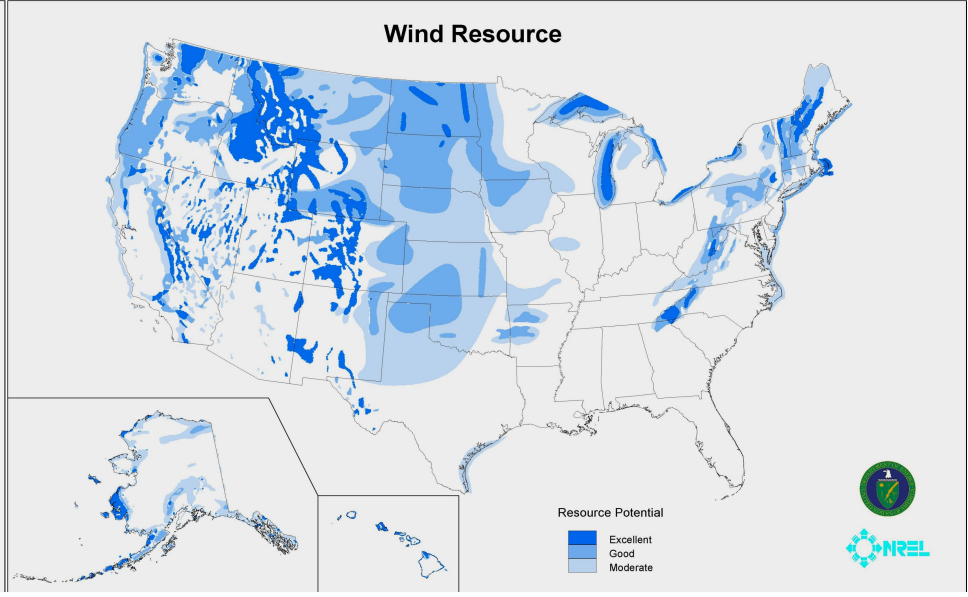
Geothermal Resource



Solar Resource



Wind Resource



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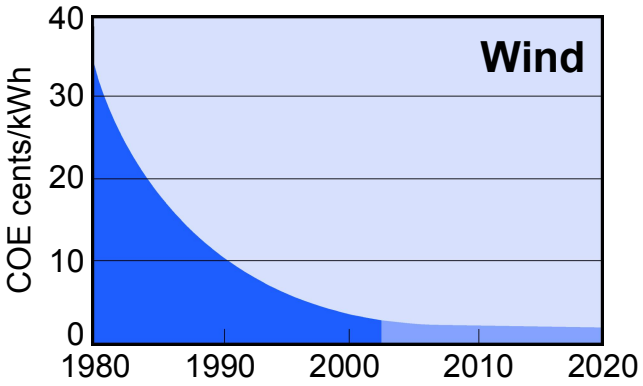
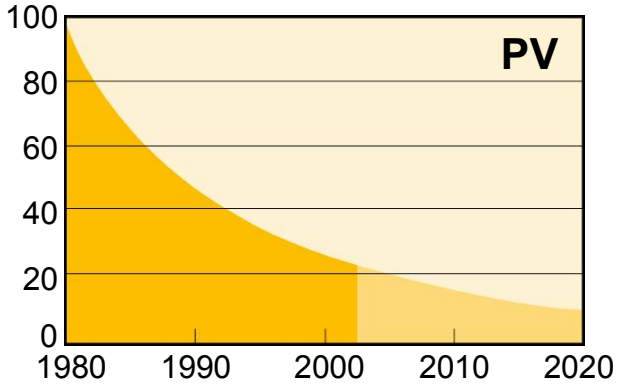
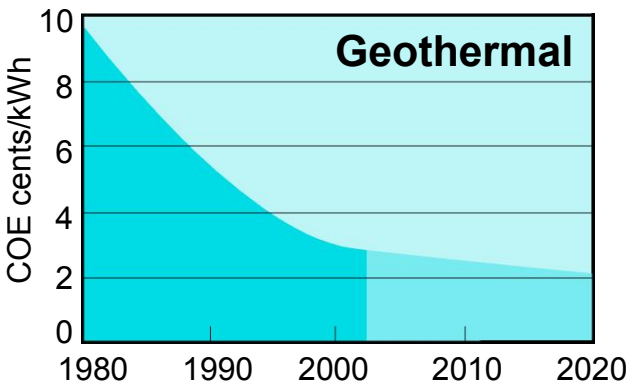
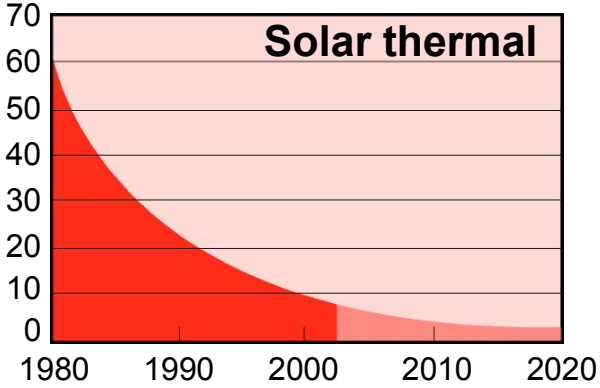
Renewable Energy Cost Trends

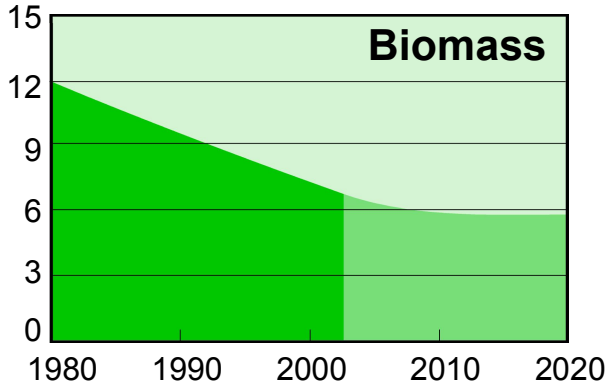
Levelized cents/kWh in constant $2000[1]









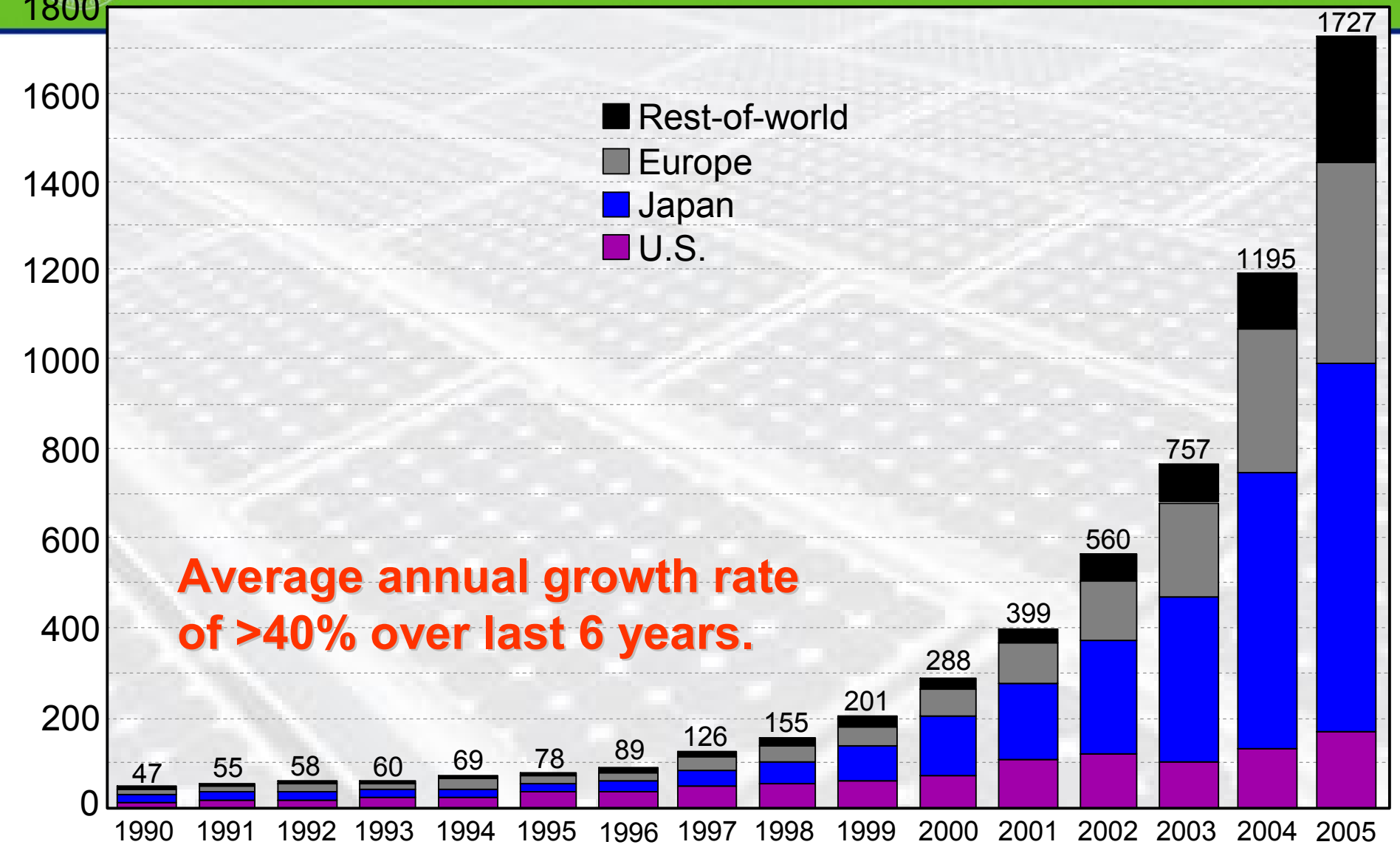


Source: NREL Energy Analysis Office (www.nrel.gov/analysis/docs/cost_curves_2002.ppt)
[1]These graphs are reflections of historical cost trends NOT precise annual historical data.
Updated: October 2002

Photovoltaics (PV)

- PV converts sunlight directly to electricity
  - Building-Integrated Photovoltaics (BIPV) - Systems where PV elements are integral part of the building & replace part of building skin costs
- Small Grid Connected ($6-20/watt)
  - 1 kilowatt or less
  - PV modules typically 50% or less of total cost
  - Other costs - inverters, other balance-of-system, installation
- Small Off Grid with Batteries, etc ($13-25/watt)
- Considerations:
  - Incentives (see http://www.dsireusa.org/)
  - Cost of alternatives (utility rates, diesel, utility line extension, etc)
  - Type of PV
  - Area required (lower efficiency modules→ more area required)
  - Resource quality

World PV Cell Production (MW)



Source: Paul Maycock, *PV News*, March 2006

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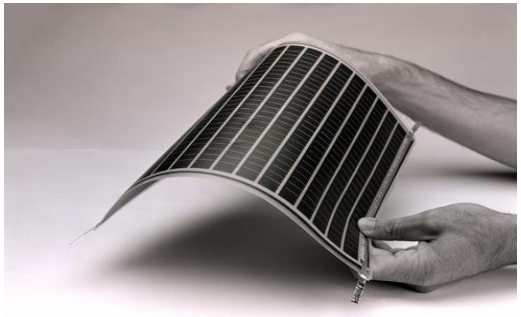
PV/BIPV Examples

PV Lighting
PJKK Federal Building, HI

BIPV, Mauna Lani Hotel

BIPV
4 Times Square, NY City
(Broadway & 42nd Street)



Naval Air Station N. Island

924 kW PV system providing shaded parking for 444 vehicles.

World's Largest PV Installations

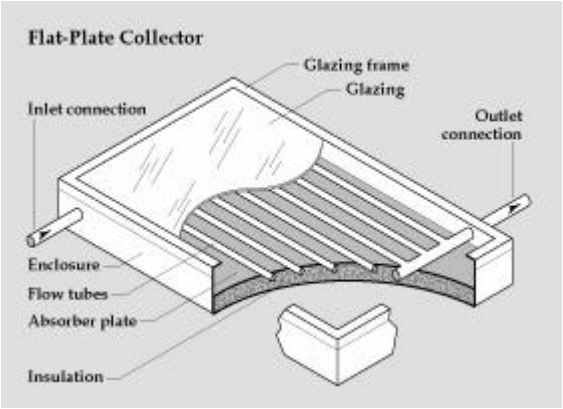
- 13 installations 4 MW or greater
- World's largest - 12 MW plant in Germany
- Largest US - 4.6 MW in Tucson, AZ
- 62 MW in development (Portugal)

Source: http://www.pvresources.com/en/top50pv.php

Solar Hot Water

Low temperature system

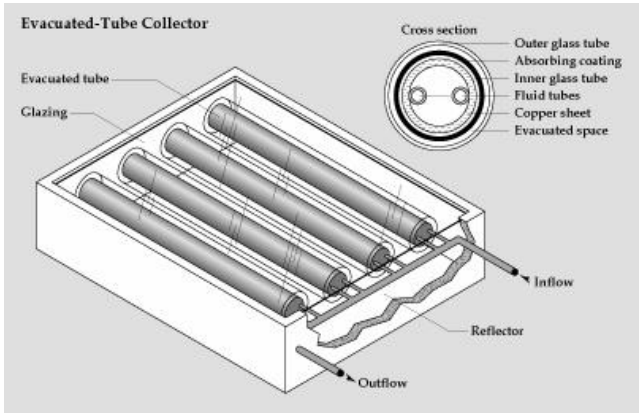
- Unglazed mats
- Glazed and insulated



Residential hot water
Swimming pools

Medium temperature system

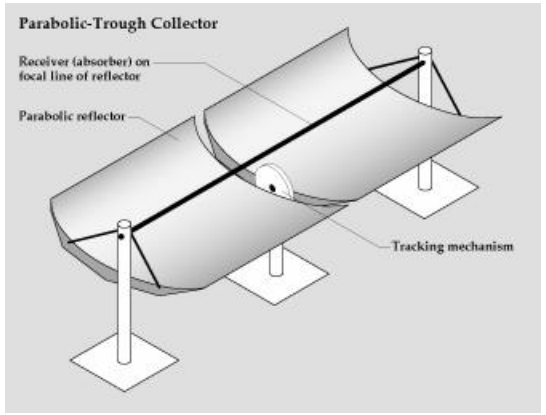
- Evacuated tubes



Cafeterias
Laundries

High temperature system

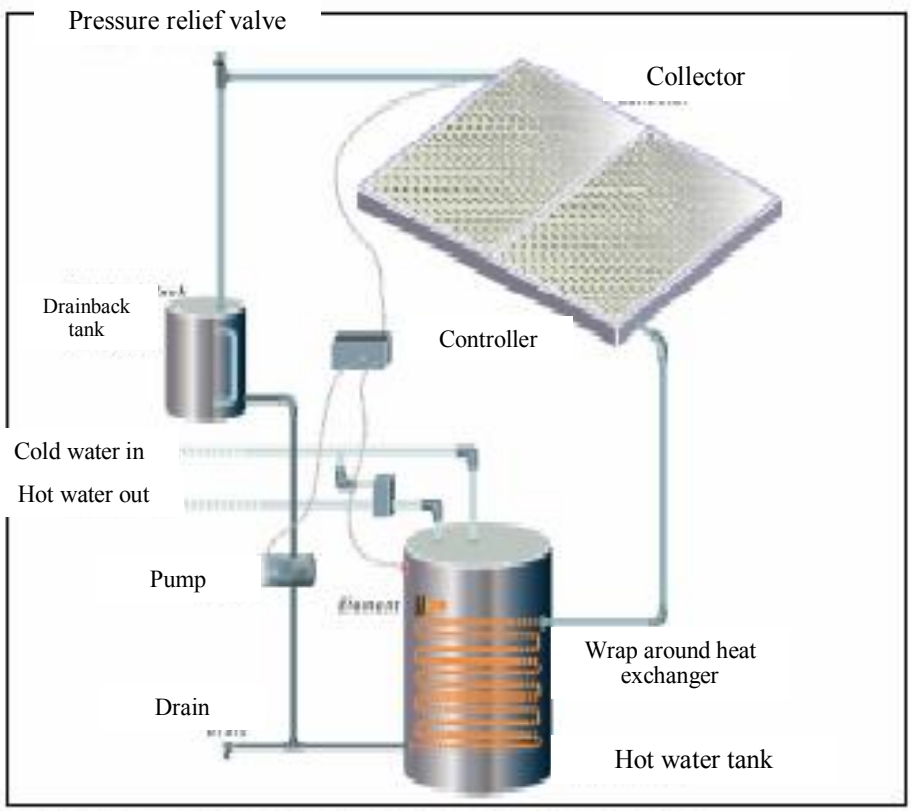
- Parabolic Concentrators



Industrial processes
Electrical generation

When to Use Solar Water Heating

- Water heating loads constant throughout week and year (or more load in the summer)
- High cost of backup energy (electricity, propane, etc.)
- Sufficient area to site collectors (1 ft^2/gal/day)
- Sunny climate helps but is not a requirement. Solar hot water works in cold & warm climates.



Drainback Solar Water Heating System

Federal SHW Examples

USCG Kia'i Kai Hale Housing Area, Honolulu, HI

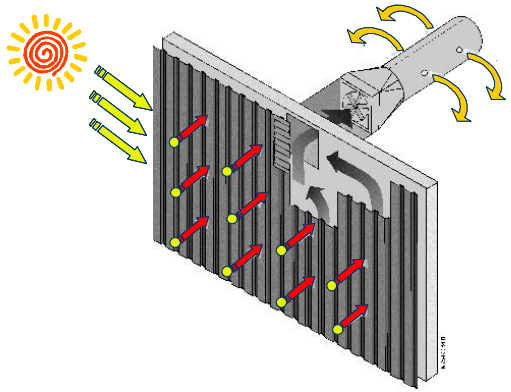
Barnes Field House, Fort Huachuca, AZ

EPA Edison, New Jersey

Phoenix Federal Correctional Institution
http://www.eere.energy.gov/femp/pdfs/33211.pdf

Solar Ventilation Preheat

- High ventilation requirements
- New construction
- Retrofit - available south wall area with fan intake



Concentrating Solar Power

- Concentrating Solar Power (CSP) Operation
  - Concentrates & focuses sunlight onto a receiver mounted at the system's focal point
  - Receiver absorbs sunlight and heats working fluid
  - Working fluid is used in engine to produce electricity

- Requires a very good, direct solar resource

- Technologies
  - Parabolic Troughs
  - Dish/Engine Systems
  - Power Towers

- Western Governor's Association (WGA) - 30GW of clean energy by 2015 goal, including 1 GW CSP

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Concentrating Solar Power

Dish Stirling

Trough
Mojave Desert, California

Solar One Power Tower
Daggett, California

Research Focus in Solar

- Higher efficiency cells
- Advanced manufacturing techniques & lower production costs
- Cheaper/less material
- New nanomaterials applications
- Concentrating PV

Bottom line – reduce ¢/kWh

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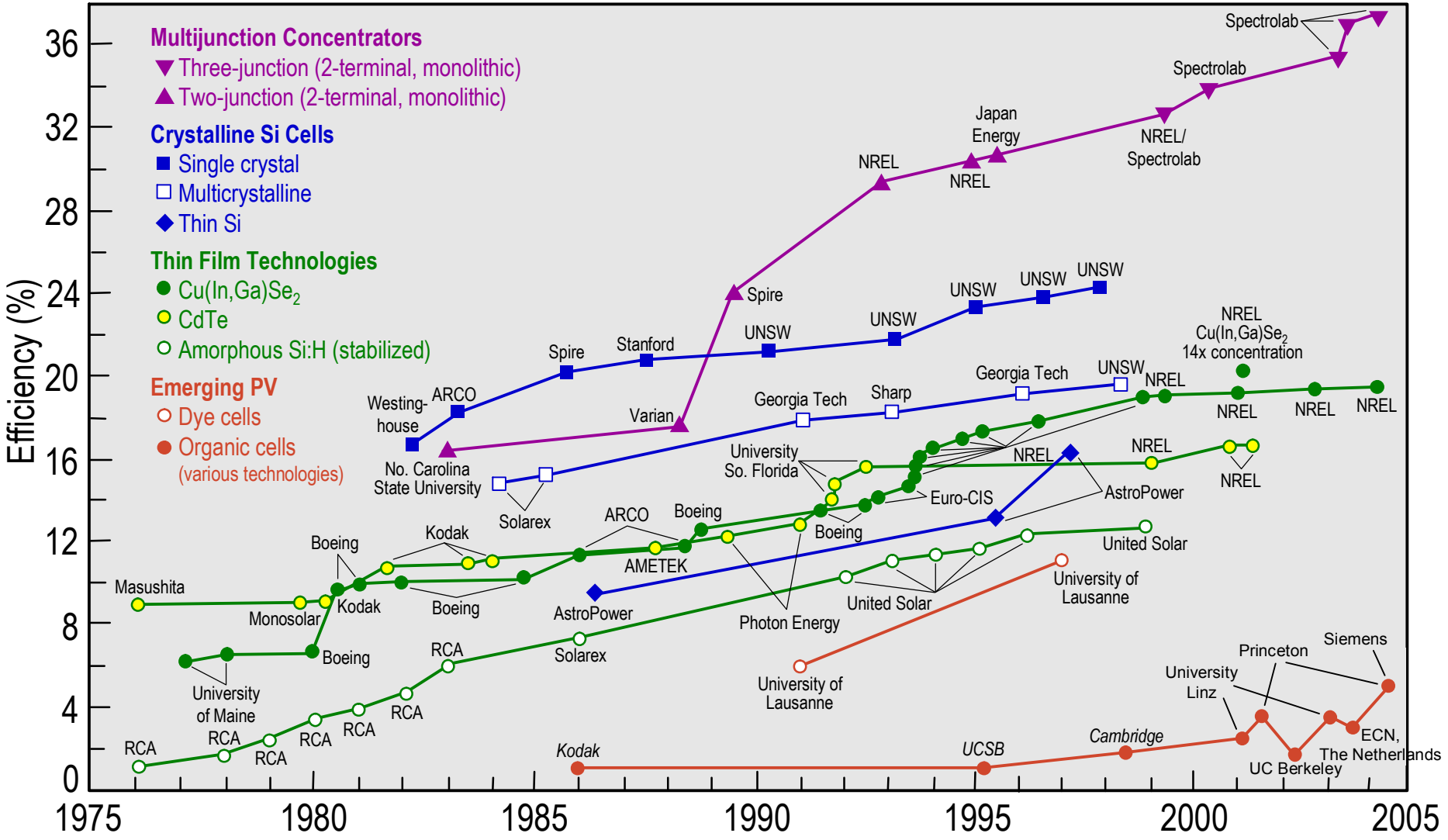
Best Research Solar Cell Efficiencies



Advanced "3rd-Generation" Solar

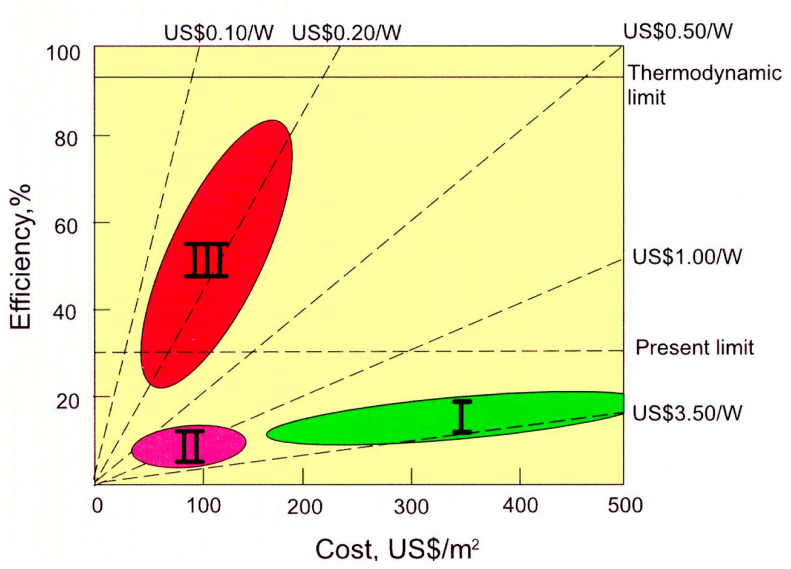
Current Technologies

I. 1st Generation – Crystalline
   - ✠ Expensive & low efficiency

II. 2nd Generation (Polycrystalline Thin Film)
   - ✠ Cheaper, but still low efficiency

Future Possibilities

I. 3rd Generation
   - ✠ Multi-junction cells (>30% efficiency)
   - ✠ Quantum dots (>60% efficiency)



Region III indicates potential efficiencies higher than previous theoretical limits, at lower costs, made possible by nanostructures such as quantum dots

Wind Power

Resource:

Wind power is created by the uneven heating of the earth's surface by the sun.

Energy production is proportional to wind speed cubed (V^3)

-Wind speed increases with height

Sizes and Applications

Small (≤10 kW)

- Homes (Grid connected)
- Farms
- Remote Applications

(e.g. battery changing, water pumping, telecom sites, icemaking)

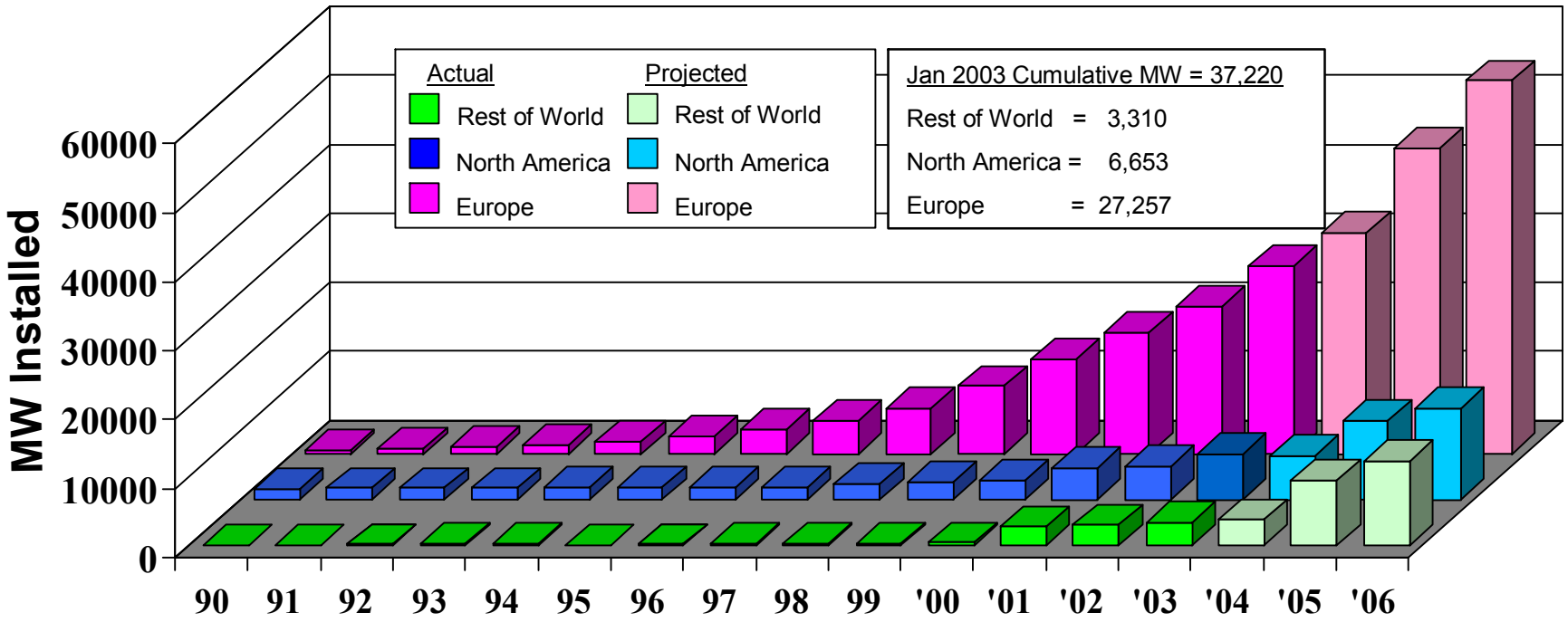
Intermediate (10-500 kW)

- Village Power
- Hybrid Systems
- Distributed Power

Large (500 kW – 6 MW)

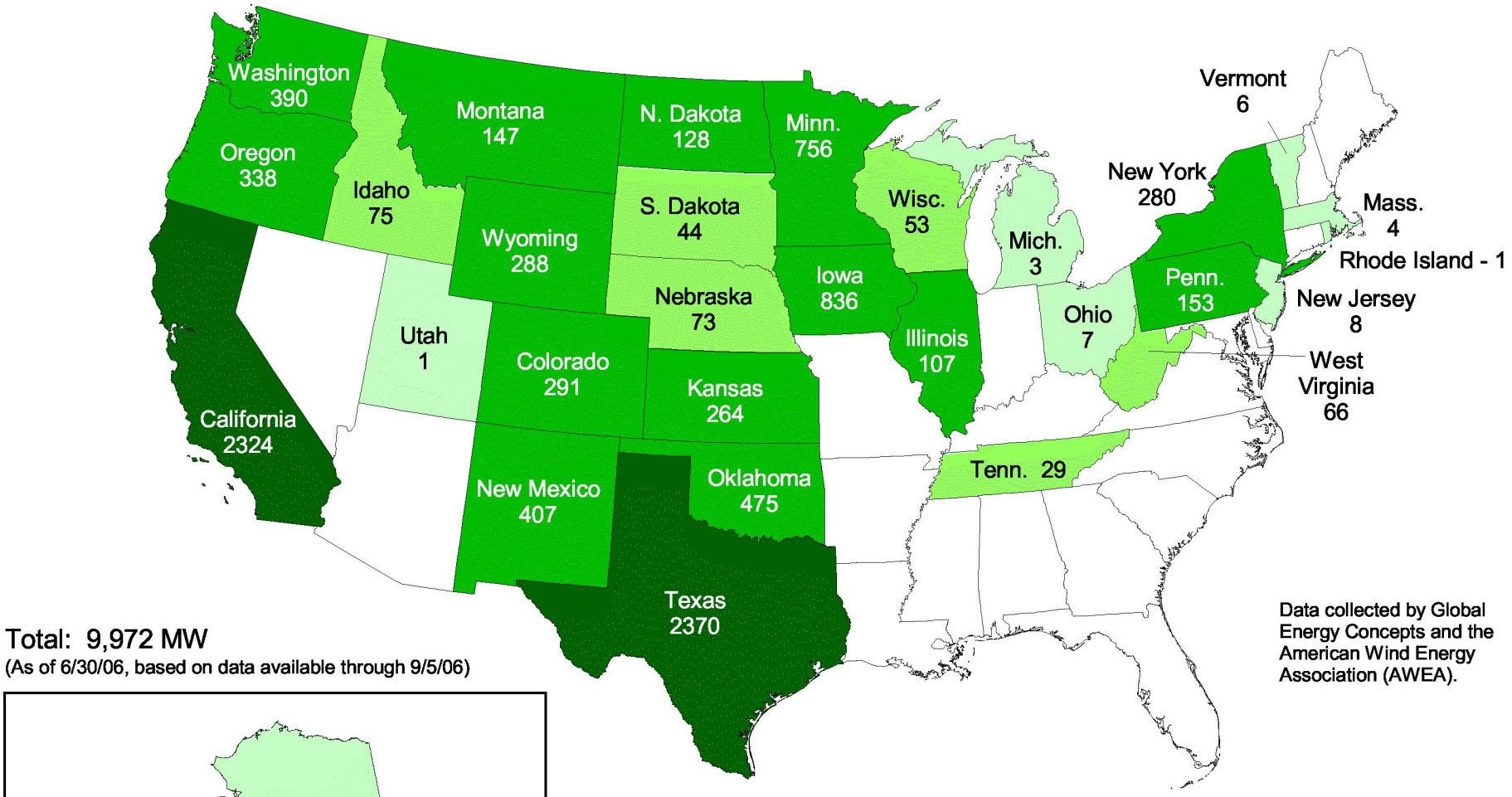
- Central Station Wind Farms
- Distributed Power
- Offshore Wind Generation Stations

Growth of Wind Energy Capacity Worldwide



Sources: BTM Consult Aps, March 2003
Windpower Monthly, January 2004
*NREL Estimate for 2004

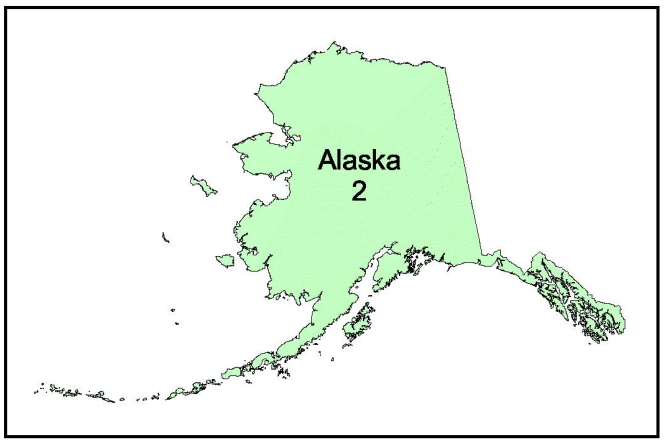
United States - Current Installed Wind Power Capacity (MW)

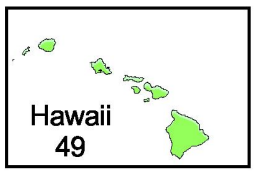


Total: 9,972 MW

(As of 6/30/06, based on data available through 9/5/06)

Data collected by Global Energy Concepts and the American Wind Energy Association (AWEA).





Wind Power Capacity

Megawatts (MW)

- 1,000 - 2,150
- 100 - 1,000
- 20 - 100
- 1 - 20

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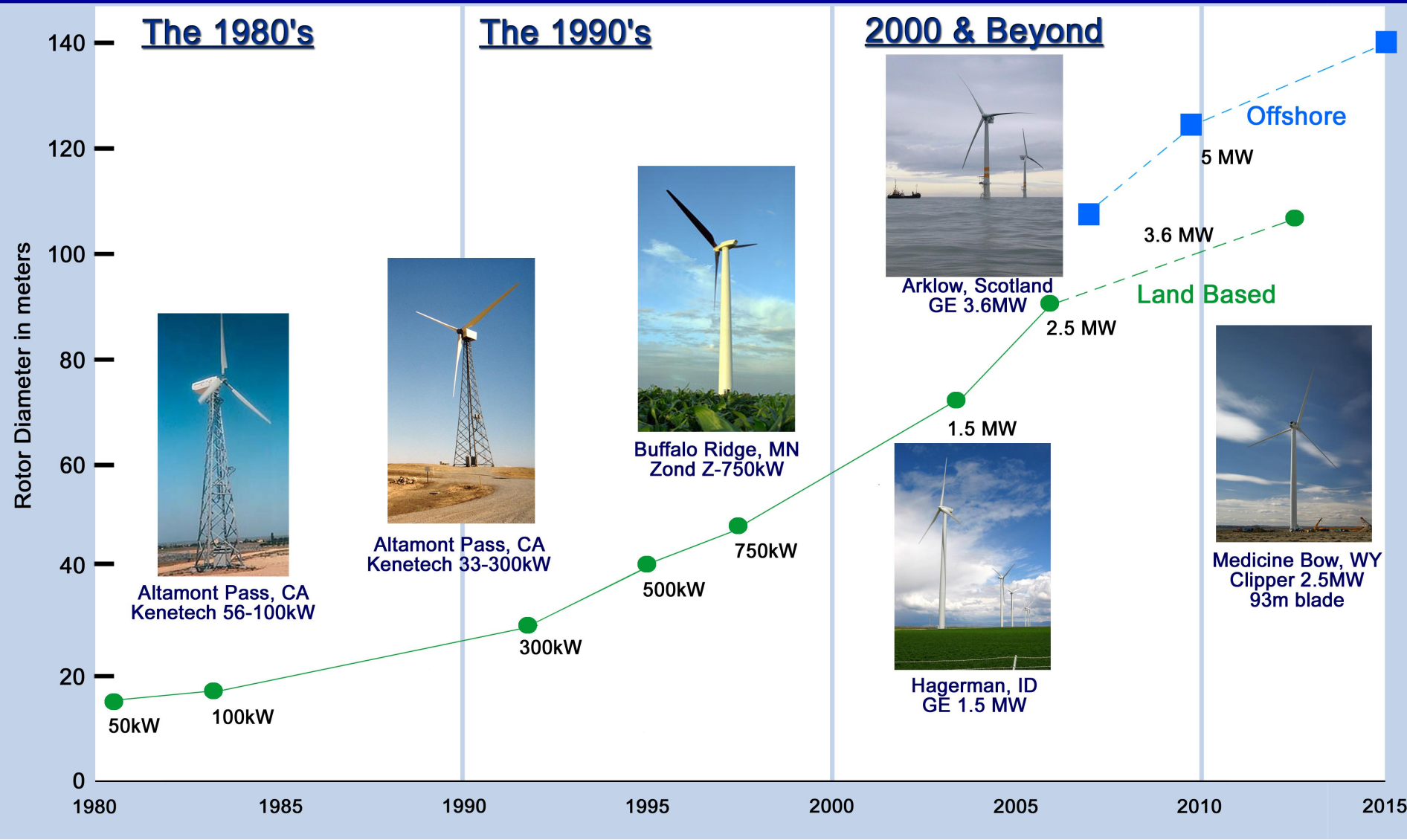
National Renewable Energy Laboratory

NREL

07-SEP-2006 1.1.23

Evolution of U.S. Commercial Wind Technology



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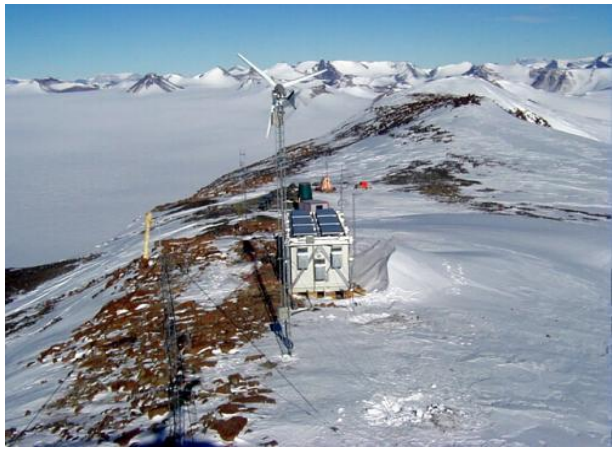
Federal Wind Examples



Research Focus in Wind

- Technology transfer to ocean-based systems
- Low-wind speed turbines (LWST)
- Better aerodynamic blades, new materials
- Advanced power electronics

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The New Bio-Industry

Biomass Feedstock

– Trees
– Grasses
– Agricultural Crops
– Agricultural Residues
– Animal Wastes
– Municipal Solid Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Combustion
- Co-firing

USES

Fuels:
– Ethanol
– Renewable Diesel

Power:
– Electricity
– Heat

Chemicals
– Plastics
– Solvents
– Chemical Intermediates
– Phenolics
– Adhesives
– Furfural
– Fatty acids
– Acetic Acid
– Carbon black
– Paints
– Dyes, Pigments, and Ink
– Detergents
– Lubricants
– Etc.

Food and Feed and Fiber

… and new concepts from plants to products

Biomass/Biofuels

Biofuels status

- Biodiesel – 75 million gallons (2005)
- Corn ethanol
  - 81 commercial plants
  - 3.9 billion gallons (2005)
  - Today's cost ~$1.35/gallon of gasoline equivalent (gge)
- Cellulosic ethanol
  - Projected commercial cost ~$3.00/gge

Potential

- 2012 goal – cellulosic ethanol ~$1.42/gge
- 2030 goal – 30% of motor gasoline

Source: U.S. Department of Energy, National Biodiesel Board, Renewable Fuels Association

Biomass Issues/Research

- Feedstock issues
  - Crop production cycle
  - Drying and storage - potential degradation problems
  - Transportation
  - Varying feedstock characteristics

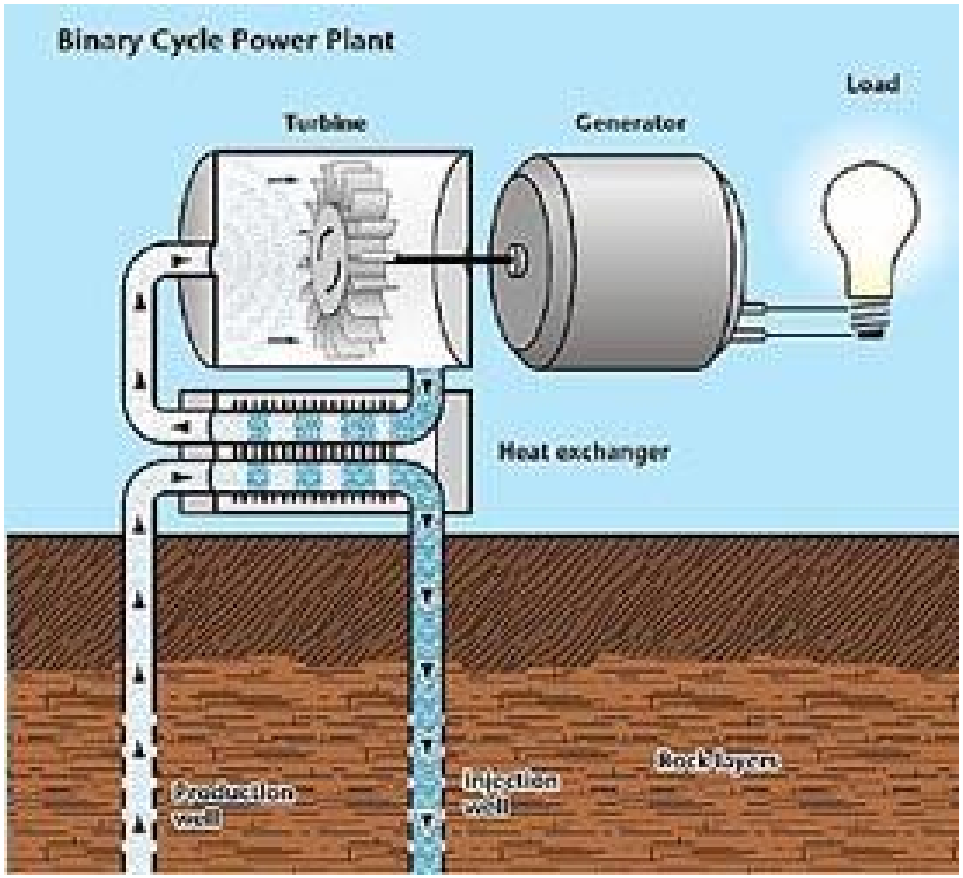
- New feedstocks - advanced energy crops, under-utilized waste

- “Biorefinery Concept”

Geothermal Energy

Resource:

Geothermal energy, energy from heat and hot water in the Earth, can provide heat or electricity.



Technologies

- Geothermal heat pumps: Use moderate temperatures of shallow ground to heat and cool buildings
- Geothermal direct use: Heat produced directly by the hot water within the Earth
- Geothermal electricity: Uses Earth's and steam of natural geysers to produce power - 2800 MW of capacity exists in U.S.

Renewable Power Purchasing (RPP) Options

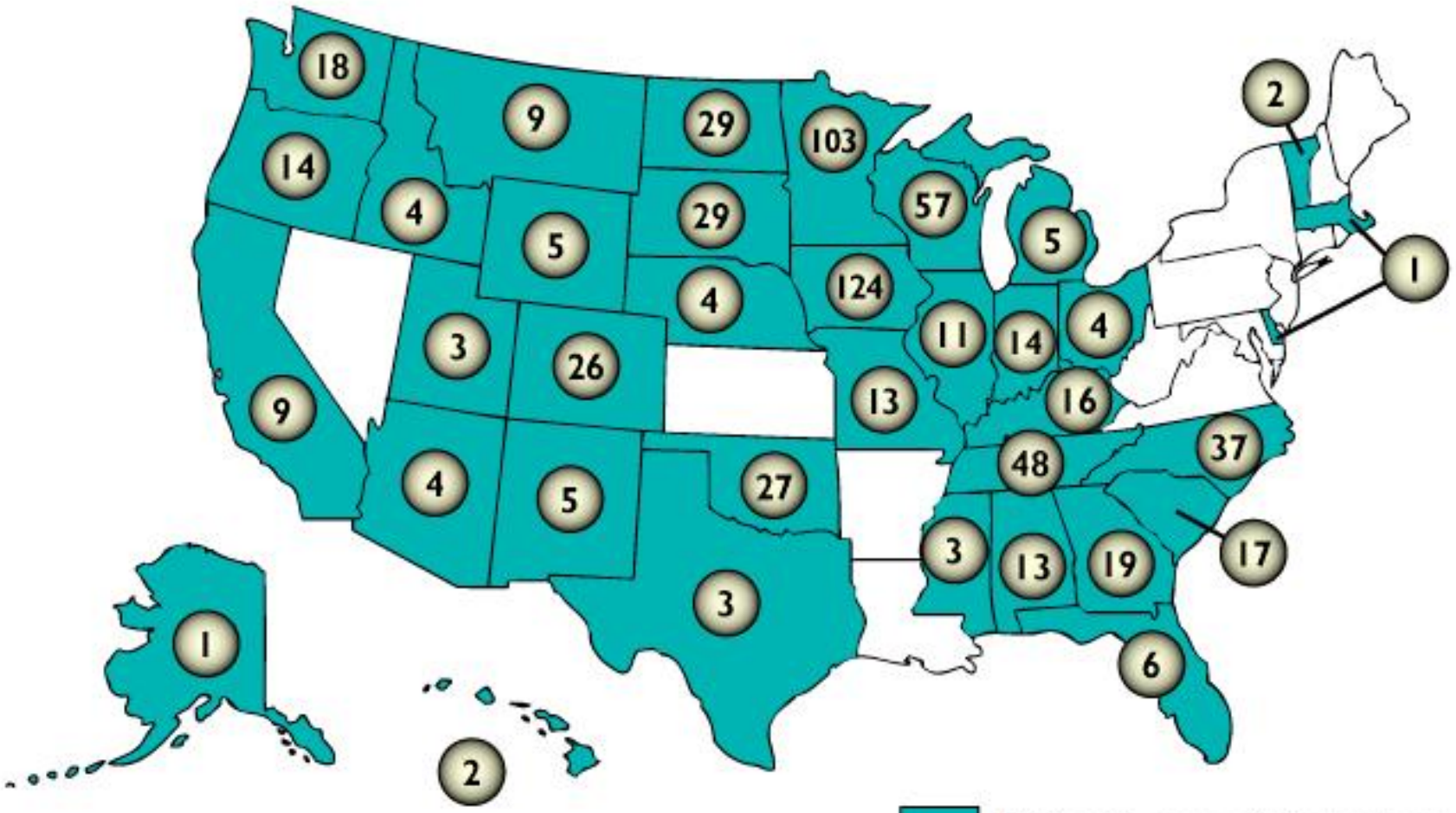
- **Utility Green Pricing Programs**
  - Voluntary programs that allow customers to purchase renewable power from their utility
  - Competitive procurement not required
  - Best programs exempt renewable customers from fuel cost adjustments (ex. Austin Energy, Xcel Energy)

- **Competitive Electricity Market**

- **Renewable Energy Certificates (REC)**
  - Renewable attributes unbundled from electricity
  - Competitive procurement
  - Typically the lowest cost option

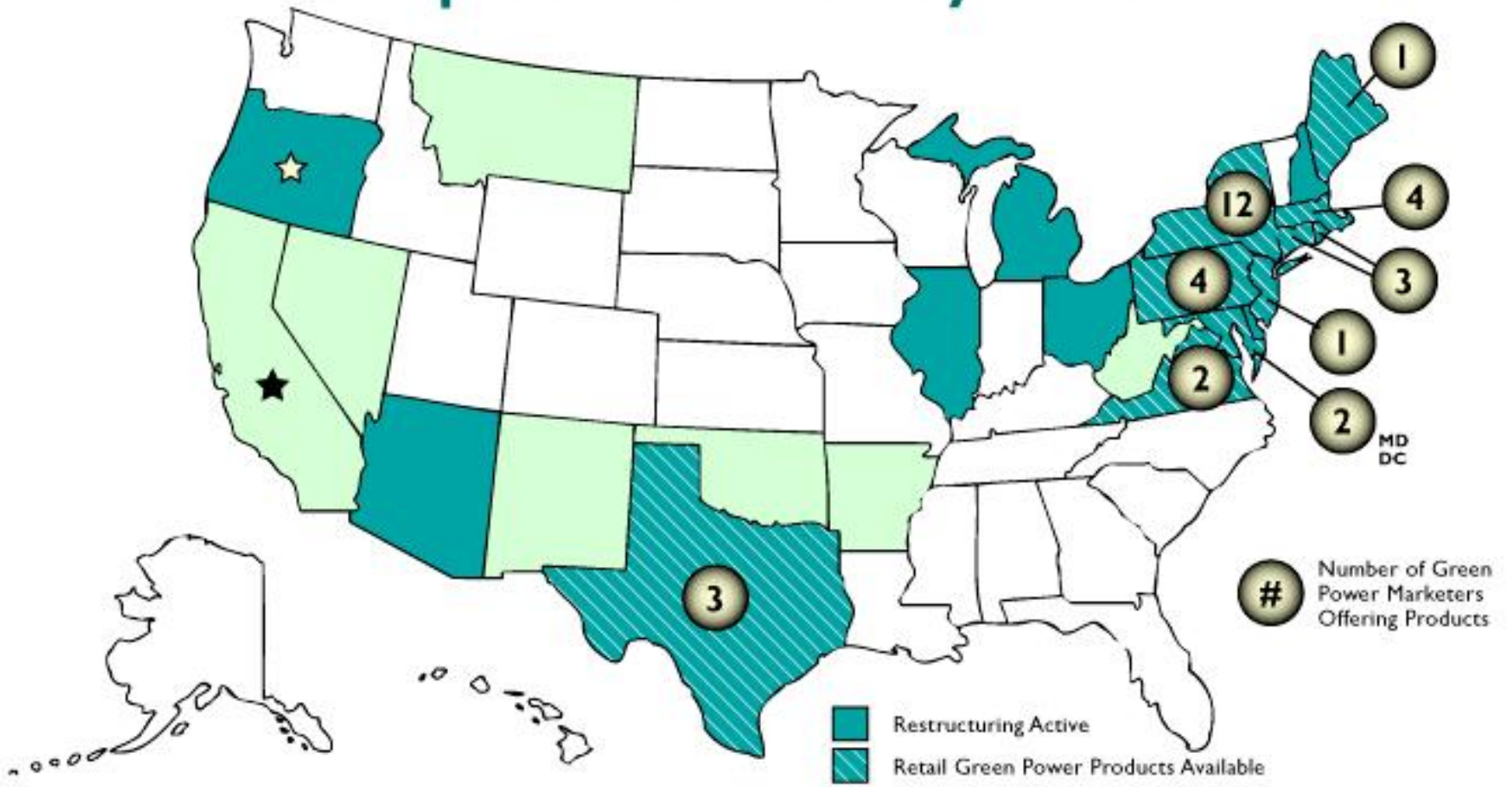
Long term renewable power purchase contracts are strongly encouraged!

Utility Green Pricing Activities



Source: National Renewable Energy Laboratory (July 2006)

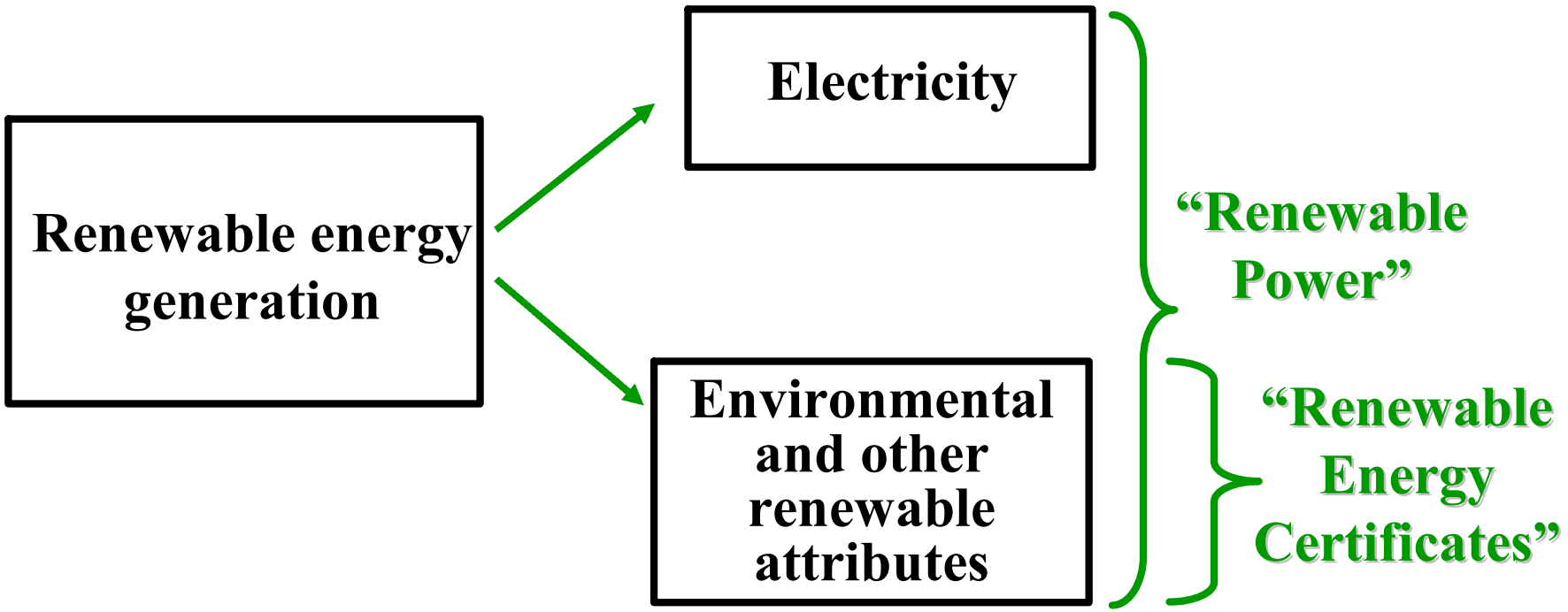
Green Power Marketing Activity in Competitive Electricity Markets*



* Represents bundled renewable electricity products available to residential and small commercial customers.

Sources: Energy Information Administration and NREL (July 2005)

REC Diagram


Renewable energy generation
Electricity
Environmental and other renewable attributes
"Renewable Power"
"Renewable Energy Certificates"

RPP Activity

- Western Area Power Administration's Federal Renewable Program – Purchases for Edwards AFB, Kirtland AFB, Fort Carson, Fort Lewis, NASA Ames, various DOE facilities, USFS, various EPA facilities

- Long term renewable power purchases (in progress) – GSA in Texas, Fort Carson & AFB in Colorado Springs Utilities service territory

- On-site PV/wind projects - Private ownership with federal agency electricity purchase
  - GSA Sacramento PV, Nellis AFB PV

- Other REC purchases (primarily through DESC)

Federal Renewable Power/REC Procurement Contacts

- Defense Energy Support Center (DESC)
  - John Nelson (703) 767-8523, john.nelson@dla.mil
  - Andrea Kincaid (703) 767-8669, andrea.kincaid@dla.mil

- General Services Administration (GSA)
  - Ken Shutika (202) 260-9713, ken.shutika@gsa.gov

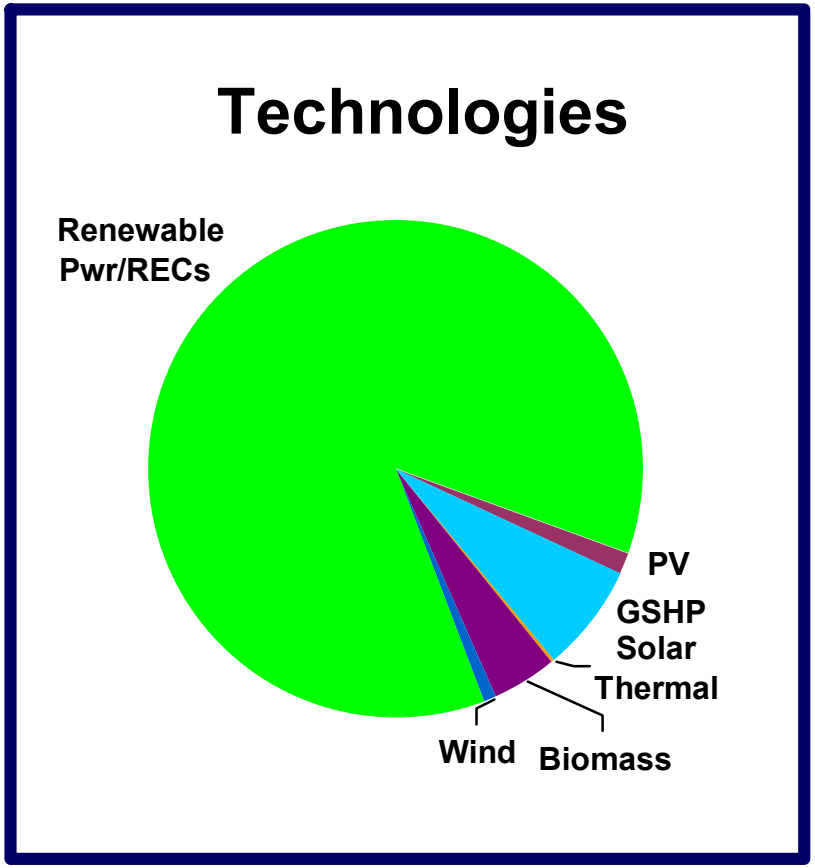
- Western Area Power Administration (Western)
  - Theresa Williams (720) 962-7170, twilliam@wapa.gov
  - Chandra Shah (303) 384-7557, chandra_shah@nrel.gov

- Bonneville Power Administration (Bonneville) - option for sites with a power allocation (ex. Fairchild AFB, DOE Richland)
  - Debra Malin (503) 230-5701, djmalin@bpa.gov

Federal Renewable Use
(As of Sept 2005)

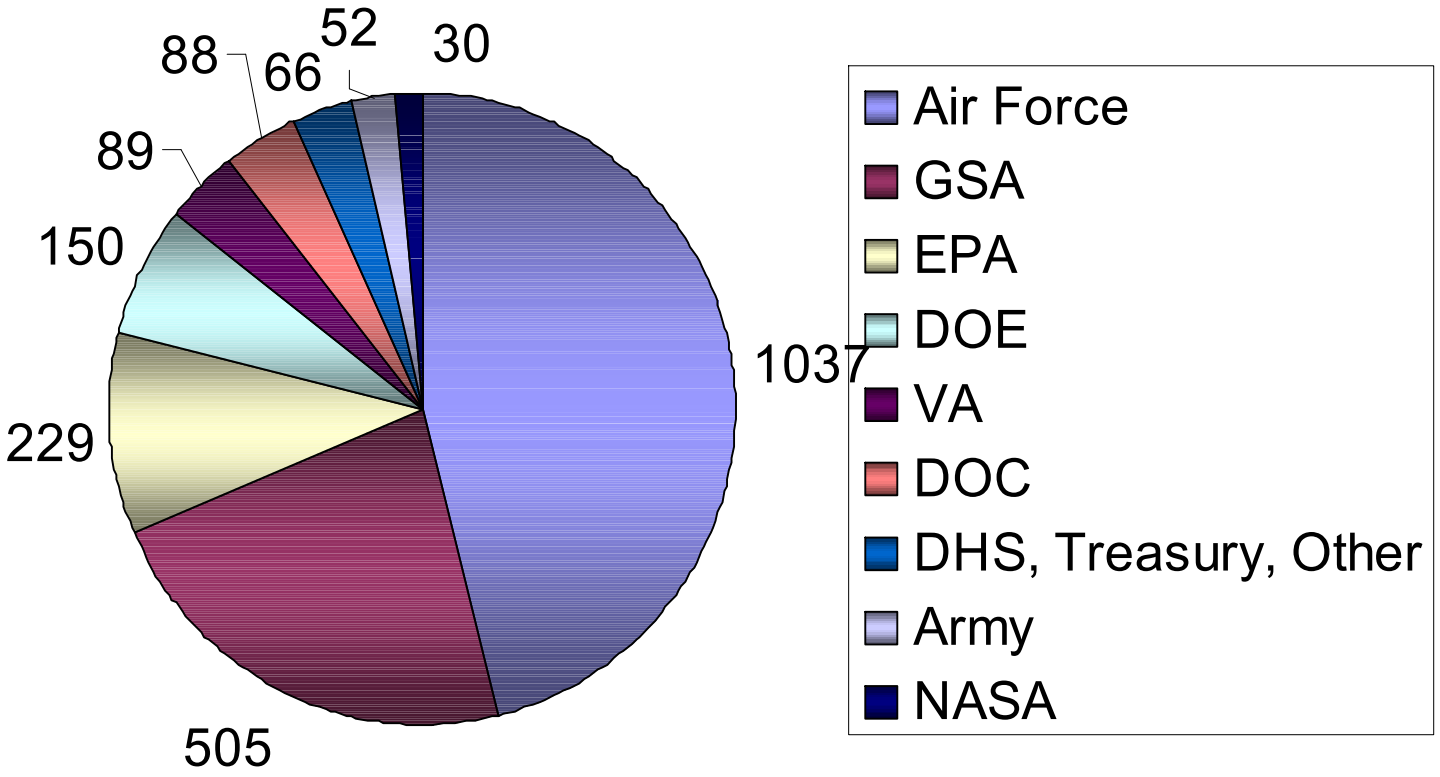
Renewable Power/RECs	2246	GWh
Ground Source Heat Pump	179	GWh
Biomass Thermal	108	GWh
Photovoltaics (PV)	34	GWh
Wind	18	GWh
Solar Thermal	10	GWh
TOTAL	2595	GWh*

*2.5% = 1395 GWh



Federal Renewable Use
(As of Sept 2005)

Who is Buying Renewable Power/RECs?



FEMP & NREL Assistance

- Project Assistance
  - Project Financing – Energy Savings Performance Contracts (ESPC), Utility Energy Service Contracts (UESC)
  - Renewable Projects
- Renewable Screening –FRESA, HOMER, etc
- Training
  - Renewables Course
  - ESPC, UESC and other workshops
- Communications
  - Federal Technology Alerts
  - Fact Sheets and Case Studies
  - FEMP Focus
  - Web Site

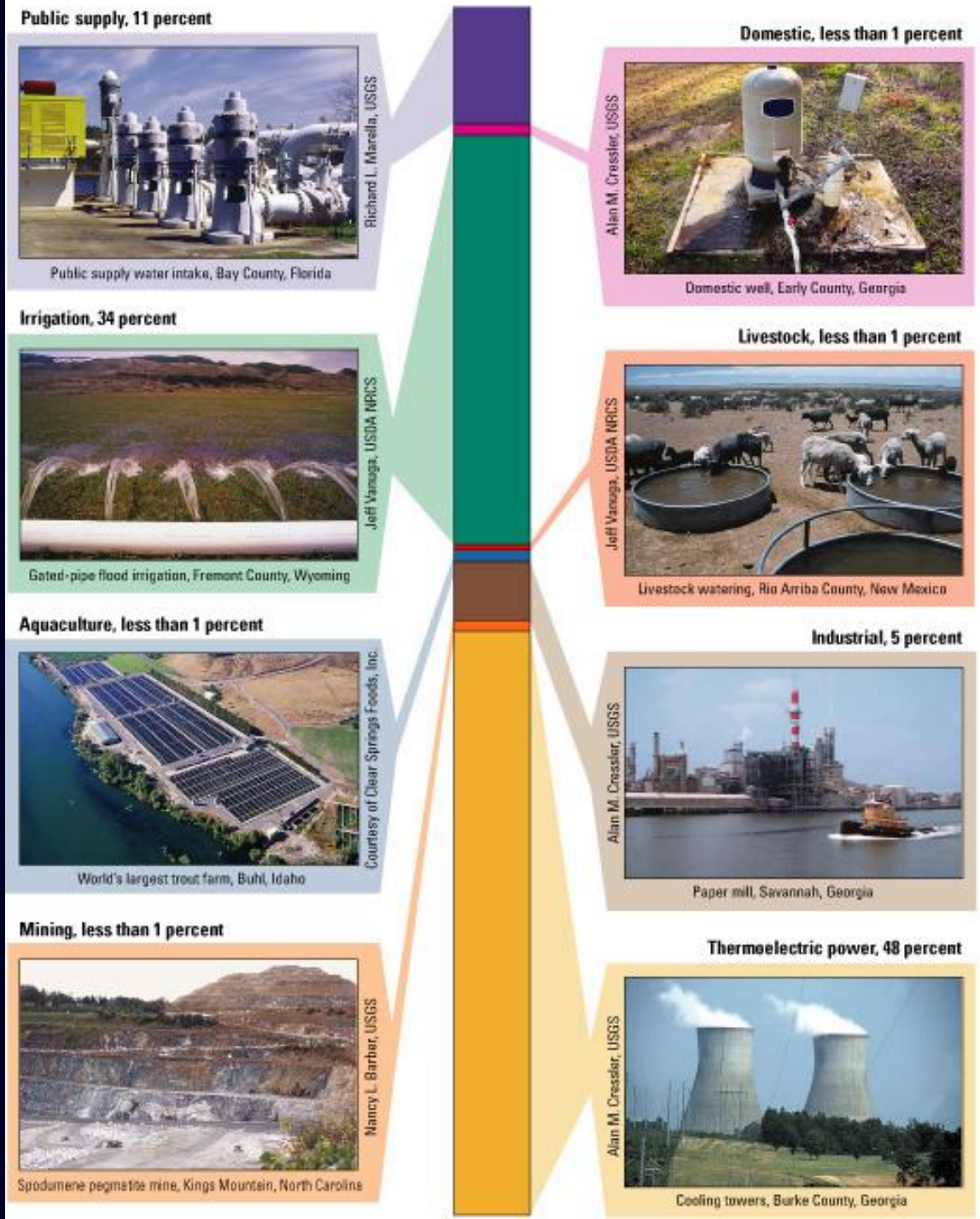
http://www1.eere.energy.gov/femp/

http://www.nrel.gov/

Why Use Renewables?

- Volatile energy market – price risk management
- Reduce dependence on fossil fuel imports – "homegrown" energy instead
- Fuel diversity
- Economic development
- Market transformation
- Lead by example
- Reduced air emissions, mining and transportation impacts and other environmental impacts
- Demonstrate environmental stewardship
- Water

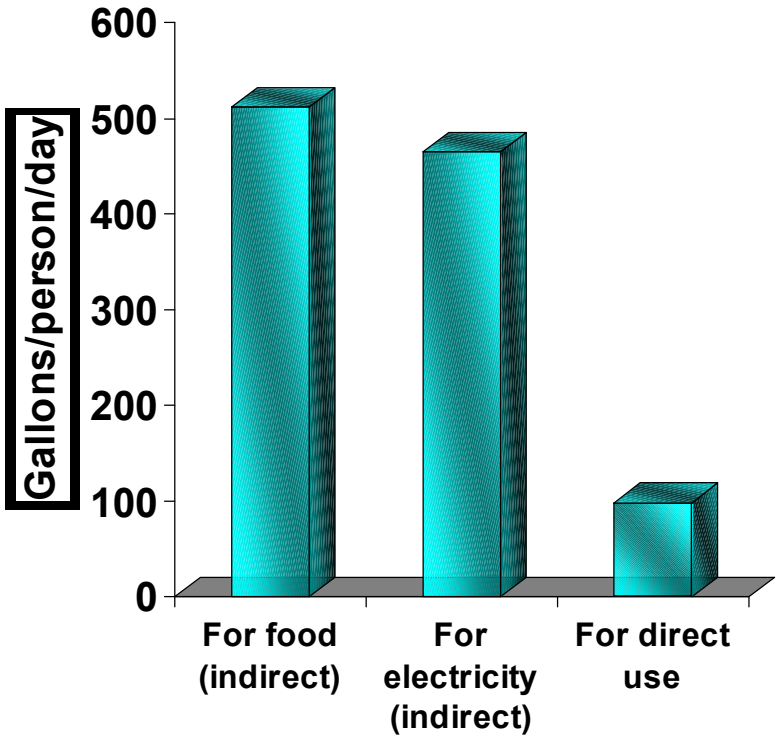
Total Water Withdrawals, 2000



Source: **USGS Circular 1268, 15 figures, 14 tables** (released March 2004 and revised April and May 2004). Available at: http://water.usgs.gov/pubs/circ/2004/circ1268/index.html

Energy Requires Water

Water used to produce household electricity exceeds direct household water use



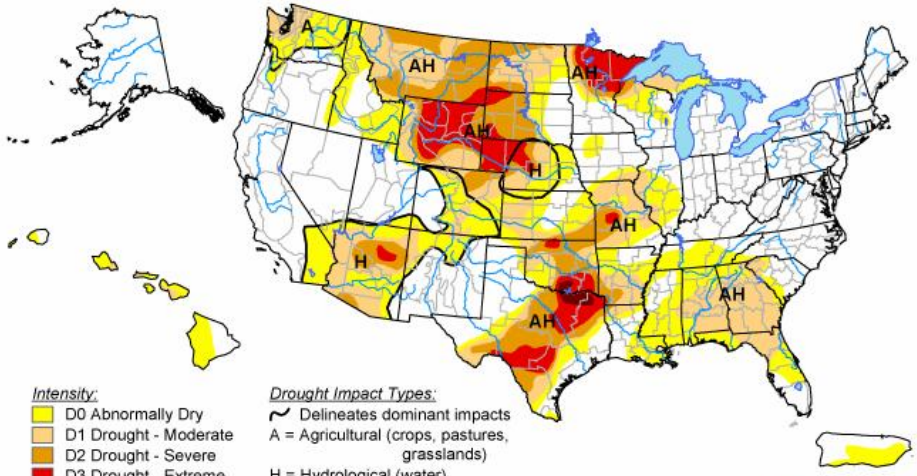
GALLONS PER PERSON PER DAY

- 510 for food production
  - includes irrigation and livestock
- 465 to produce household electricity
  - Range: 30 to 600 depending on technology
- 100 direct household use
  - includes bathing, laundry, lawn watering, etc.

Source: derived from Gleick, P. (2002), *World's Water 2002-2003*.

U.S. Drought Monitor

October 17, 2006
Valid 8 a.m. EDT



Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:
- Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

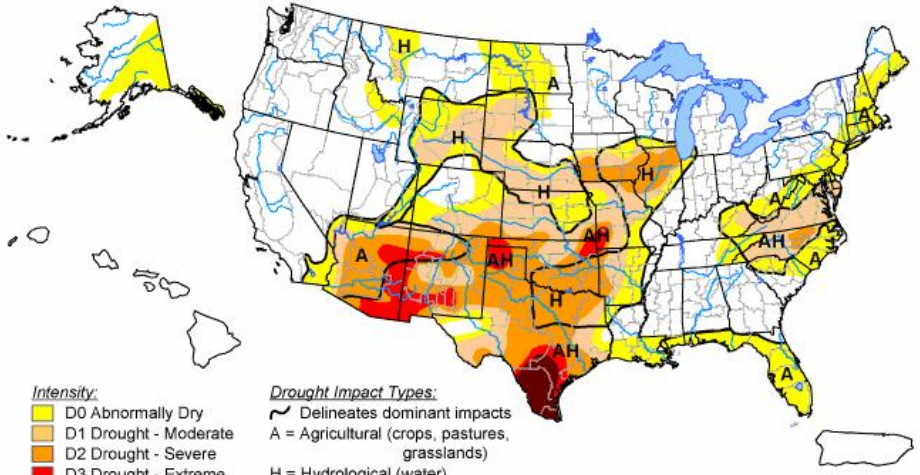
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, October 19, 2006
Author: Ned Guttman/Liz Love-Brotak, NOAA/NESDIS/NCDC

U.S. Drought Monitor

March 28, 2006
Valid 7 a.m. EST



Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:
- Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)
- (No type = Both impacts)

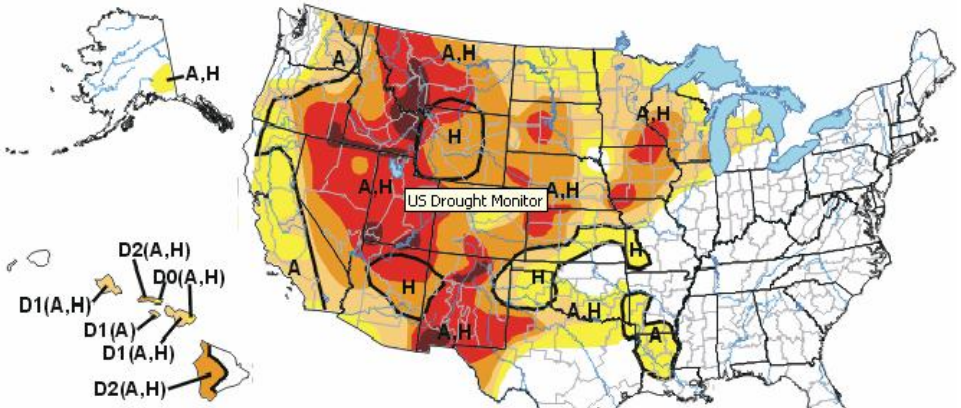
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, March 30, 2006
Author: C. Tankersley/L. Love-Brotak, NOAA/NESDIS/NCDC

U.S. Drought Monitor

October 28, 2003
Valid 8 a.m. EST



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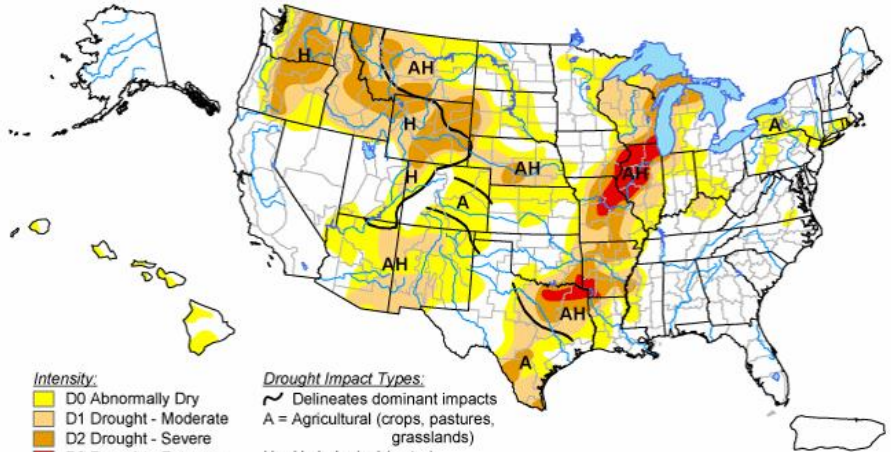
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary

U.S. Drought Monitor

August 2, 2005
Valid 8 a.m. EDT



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Drought Impact Types:
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The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, August 4, 2005
Author: Michael Hayes, NDMC

Humanity's Top Ten Problems for next 50 years

1. **ENERGY**
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

2003	6.3	Billion People
2050	9-10	Billion People

Source: Nobel laureate, Richard Smalley

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